A method for estimating the lighting quality of vehicle headlights

A matter of the invention is a method for estimating the lighting quality of vehicle headlights particularly automobile headlights.

The invention has an application in the vehicle control stations as well as in the laboratories for testing of vehicle headlights, especially automotive headlights during the process of its designing, constructing and exploitation.

In Regulation No 20 of the United Nations Organisation – Economic Commission for Europe – E/ECE/324-E/ECE/TRANS/505/Rev. 1/Add. 19/Rev.2. –is described a method of estimation the lighting quality of car headlights. The method relies upon that the light beam emitted from the tested vehicle headlamp is projected on the screen situated pérpendicularly to the optical axis of the headlamp and in the fixed distance from it. Then in the definite points and areas of that screen the illumination is measured by luxmeter and the results of these measurements are indicated in a table and compared with the required values. There is a modification of this method in which the values of the tested headlamp illumination are obtained by measuring the luminous intensity of the headlamp by goniophotometer in a solid angle of the emitted light beam.

The main disadvantage of the described methods is that the estimation of the lighting quality of the vehicle headlights is being taken only for one headlamp and that the values of illumination are obtained from the surface of

a screen situated perpendicularly to the emitted light beam. However, the surface of the screen does not reflect the road surface observed by a driver. The driver observes the road and its closest surrounding on a surface which is parallel to the optical axis of car headlamps. Furthermore, in the described methods the lighting quality is estimated for the constant distance between the tested headlamp and measuring device, and for these conditions the requirements are defined, whereas, the illuminated points of the lighting road are in different distances depending on the setting of headlamps on the vehicle. Therefore, the described methods do not correspond to the real conditions of illuminated objects observed on a road and they do not reflect the real lighting characteristics, for one vehicle headlamp and especially for the set of headlamps installed on a vehicle. In fact, the distribution of illumination of vehicle headlamps is entirely different on the road surface from the one on the screen. Therefore, the measured results do not correspond to the real illumination conditions existed on the road and consequently the estimation of the lighting quality of tested headlamp is incorrect.

A method according to the invention is free of the disadvantages described above.

The matter of the invention relies on that the obtained distribution of illumination on a screen or the luminous intensity in a solid angle for each tested headlamp is first transformed, by the known geometric methods, to the real distribution of vertical illumination on the road surface, where the vertical illumination means the illumination on the plane perpendicular to the vehicle axis and then all the such obtained distributions of vertical illumination for each headlamp of the tested set are summarised giving a final distribution of vertical illumination E_d . In the same way, the real distribution of vertical illumination on the surface parallel to the road, lying on the eye-level of the glared drivers, is calculated and then all the such obtained illumination distributions for each headlamp of the tested set are summarised giving a final distribution of vertical illumination E_o .On the basis of these results some measure values of lighting quality are calculated, which are the numerical values $\mathbf{M_k}$ in the case of illumination of the road and the numerical values $\mathbf{N_l}$ in the case of the

eyes of glared drivers. Calculations are made for some numbers k of sectors S_k established for the road surface and their surrounding, and for some numbers l of sectors S_l established for the surface at the eye-level of the glared drivers. The obtained results are compared with the required values.

The numerical values M_k are calculated according to the following mathematical formula

$$M_k = \frac{\int_{S_k} E_{rd} \cdot dS_k}{a \cdot E_a S_k}$$

where E_{rd} is the value of illumination used for the calculation, on the conditions that $E_{rd} = E_d$ when $E_d \geq E_{pr}$ or alternatively $E_{rd} = 0$ when $E_d < E_{pr}$, where E_{pr} is the threshold illumination in which the human eye can see anything, E_a is the illumination on the surface of the driver's eye, caused by the light of tested headlamps and responsible for the sight adaptation level of the driver`s eye, a is a constant number which reflects proportion between the illumination on the surface of the eye and the illumination close to the road surface, dS_k is a differential of the area of tested sector k and, S_k is the whole area of the sector k.

The numerical values N_l are calculated according to the following mathematical formula

$$N_l = \frac{\int_{S_l} (E_{oe} \cdot \cos\alpha - E_{op}) \cdot dS_l}{E_{op} S_l}$$

where E_{oe} is the value of illumination used for the calculation, on the conditions that $E_{oe} = E_o$ when $E_o \cdot \cos\alpha \geq E_{op}$ or alternatively $E_{oe} = E_{op}$ when $E_o \cdot \cos\alpha < E_{op}$, where α is an angle between the sight line of the driver and the light beam causing the glare, E_{op} is the threshold glare illumination on the surface of the eye, dS_l is a differential of the area of tested sector l and, S_l is the whole area of the sector l.

The value of parameter E_a existing in the first formula is favourable to calculate from the following mathematical formula

$$E_a = \int_{\omega} L_d \cdot \cos\theta \cdot d\omega$$

or alternatively from the another mathematical formula

$$E_a = b \cdot \frac{\int_{S_e} E_{da} \cdot dS_e}{S_e}$$

where $\boldsymbol{L_d}$ is the luminance of the road observed by a driver and caused by the tested headlamps, $\boldsymbol{\omega}$ is a solid angle with its top in the driver's eye where the illuminating surface of the road exists or a part of this angle in which there is the greatest luminance of the road responsible for the sight adaptation level of the human eye, $\boldsymbol{b}$ is a constant number which reflects the proportion between the illumination on the surface of the road and the illumination on the surface of the eye, $\boldsymbol{\theta}$ is an angle between the line perpendicular to the surface of the driver's eye and the incident light beam, $\boldsymbol{E_{da}}$ is the illumination on the surface of the road which causes the luminance responsible for sight adaptation level of the drivers eyes, $\boldsymbol{S_e}$ is the area of a plane which is perpendicular to the direction of the driver's sight line and through which the light beams reflecting from the road incident to the eyes, $d\boldsymbol{S_e}$ is a differential of the area $\mathbf{S_e}$.

It is favourable when all the values of illumination and luminance used for the calculations are replaced by proportional non-linear functions, best by the logarithmic function. It is also favourable when all the above mathematical calculations are carried out by means of computerised numerical methods.

The main advantage of a method according to the invention is that it allows to evaluate the real illumination of the road surface, both for the one tested headlamp as for the set of two or more headlamps installed on the vehicle. This method enables to estimate the actual illumination quality of the vehicle headlamps on the road and their surrounding. The method uses a very important factor as a sight adaptation level of the drivers eyes to the illumi-

nated road surface and objects. By this method one can estimate the real light quality for the set of tested vehicle headlamps.

An example of the invention is showed as follow:

A set of two headlamps is tested. For each headlamp from this set, by means of a goniophotometer, the illumination distribution on the screen surface situated in the distance of 25 meters is measured. The results in digital form are stored on a computer disc. Then, by means of a computer program, the results are transformed according to the known geometrical methods to the distribution of vertical illumination on the road surface, whereas the vertical illumination is defined for the plane perpendicular to the vehicle axis. The obtained values for each of the two headlamps are summarised giving the final distribution of vertical illumination $\boldsymbol{E_d}$. Then, on the road surface some number of $\boldsymbol{k}$ sectors are established, in this example eight; S_1, S_2, ..., S_8, for whose the numerical values $\boldsymbol{M_k}$ are calculated according to the following mathematical formula

$$M_k = \frac{\int_{S_k} E_{rd} \cdot dS_k}{a \cdot E_a S_k}$$

where the constant factor $\boldsymbol{a}$ was established as $\boldsymbol{1}$, the value $\boldsymbol{E_{rd}}$ was used according to the following conditions: $\boldsymbol{E_{rd} = E_d}$ when $\boldsymbol{E_d \geq E_{pr}}$ or alternatively $\boldsymbol{E_{rd} = 0}$ when $\boldsymbol{E_d < E_{pr}}$ where $\boldsymbol{E_{pr}}$, as the treshold illumination, was used as $\boldsymbol{E_{pr}}$ = (0,05 x $\boldsymbol{E_a}$), while the value $\boldsymbol{E_a}$ was calculated from the following mathematical formula

$$E_a = b \cdot \frac{\int_{S_e} E_{da} \cdot dS_e}{S_e}$$

where the constant factor $\boldsymbol{b}$ was used as 1000, the value $\boldsymbol{E_{da}}$ was used as equal to the value $\boldsymbol{E_d}$ and the value $\boldsymbol{S_e}$, as a plane surface perpendicular to the direction of the driver`s sight line, was calculated from the relation between the illuminated road surface and the angle of observation of the driver.

In the similar way from the mathematical formula

$$N_l = \frac{\int_{S_l} (E_{oe} \cdot \cos\alpha - E_{op}) \cdot dS_l}{E_{op} S_l}$$

are calculated the values of estimation of a glare illumination for the two established sectors S_9 and S_{10} of the driver's eyes , the first one on the left side for the oncoming driver and the second one on the right side for the preceding driver.

All the above calculations were made by means of the computer program. The final result of these calculations, were the numerical values of light estimation $\boldsymbol{M_1}$, $\boldsymbol{M_2}$, ... $\boldsymbol{M_8}$, suiting for sectors S_1, S_2, ... S_8 of the illuminating road surface and the numerical values of light estimation $\boldsymbol{N_1}$, $\boldsymbol{N_2}$, correspondingly to sectors S_9, S_{10} of the glare surface. The obtained results are presented in the following table:

Sectors	Results	Requirements
Sectors of road surface	$\boldsymbol{M_k}$	$\boldsymbol{M_k}$
S_1	0.862	>0.750
S_2	0.571	>0.500
S_3	0.192	>0.150
S_4	0.027	>0.020
S_5	0.929	>0.750
S_6	0.659	>0.500
S_7	0.220	>0.200
S_8	0.046	>0.030
Sectors of glare surface	$\boldsymbol{N_l}$	$\boldsymbol{N_l}$
S_9	0.169	<0.500
S_{10}	0.278	<0.800

Comparing the obtained results with the required values, it is possible to estimate the light quality of the two tested headlamps. In this example the tested set of headlamps meets the established requirements.